CENTRAL REFRIGERATION SYSTEM FOR A PROPOSED FOOD DISTRIBUTION CENTER IN DALLAS, TEXAS

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FOREWORD

The Agricultural Research Service is making a study of food marketing facilities and methods in Dallas, Tex. The purpose of this study is to determine the adequacy of existing facilities and handling methods; the extent to which food distribution costs can be reduced; the number of distributors who need new facilities; the kinds and sizes of facilities that are needed to correct existing defects; the cost of these facilities; their possible locations; and the financial and other benefits that could be expected from developing a modern wholesale food distribution center for distributors who need to relocate.

Since most foods are perishable, adequate refrigeration is an essential feature of any food distribution center. To determine the nature and cost of such a refrigeration system for the facilities being planned and to hasten the completion of the study, Food Industry Services, a private contractor, was employed to do this phase of the work. This publication consists of the contractor's report exactly as it was written. The report is being published primarily for the use of the food wholesalers and others who may be involved in building the food distribution facilities in Dallas, Tex.

Some of the material contained in this publication will be incorporated in the report ARS is publishing, which sets forth its total findings in the study of food marketing facilities and methods in Dallas, along with its recommendations for their improvement.

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CENTRAL REFRIGERATION SYSTEM FOR A PROPOSED FOOD DISTRIBUTION CENTER IN DALLAS, TEXAS

SUMMARY

In the proposed Dallas Food Distribution Center, 70 rooms in 15 buildings would require 1,272 tons of refrigeration per hour at peak loads. The total area of the 70 rooms measures approximately 308,125 square feet, and temperature requirements range from a low of -10° F to a nominal high of 72° F for air conditioning. However, from the standpoint of refrigerant distribution and use, the proposed central refrigeration system would supply the Dallas food center with three refrigerant circuits, each with a different suction temperature at terminal evaporators: -30° F for storing frozen food, +20° F for maintaining room temperatures in cooler rooms, and +35° F for maintaining temperatures in work rooms and offices.

The proposed central refrigeration system would consist of three components: a central plant to serve as a source of refrigeration, a network of pipelines for distributing the refrigerants to users, and terminal evaporator units located in the users' rooms. The central plant would require a building with approximately 9,800 square feet to accommodate equipment and service functions, and a yard area of 6,000 square feet for condensing equipment.

The plant equipment would consist of two separate but interconnected compressor groups, six large condensing units, two large accumulators, and one large tank. This equipment would be served by a group of pumps, as well as by the necessary receivers, intercoolers, and sundry other equipment.

One electrical panel would service the control requirements of the refrigeration system, and a separate bank of transformers would supply the power required to operate the central plant.

Three main refrigeration trunk lines would emanate from the central plant to serve the three areas of the food distribution center. The pipelines would be installed in the ground in trenches and then insulated with foamed-in-place urethane. Each building would be served from a group of branch lines that extend from the trunk lines into the various rooms that require refrigeration. Terminal evaporator units would be installed in each room according to requirements, and specific temperatures would be maintained by properly sizing the evaporator coils and installing back-pressure valves and thermostats at the units.

Tapwater would be used as a secondary refrigerant for air conditioning and heating offices at a nominal 72° F. For air conditioning, a refrigerant would be used to chill the water by means of a heat exchanger. The chilled water would then be circulated through the coils of the air-conditioning units. The same system would be used for heating the offices, except that a hot gas

instead of a refrigerant would be circulated through the heat exchangers. The hot gas, furnished by the central plant, would also be used for defrosting evaporator coils in rooms with temperatures from -10° F to +36° F.

The original cost of a central refrigeration system for the Dallas Food Distribution Center is estimated to be $2.1 million. The cost of owning and operating the central refrigeration system is estimated at $703,100 per year.

Charges to firms that use refrigeration from the central plant would be determined by assessing a flat charge for each terminal evaporator and by metering the demand for refrigerant liquids to each room. Different rates would be established for each size of evaporator and each suction temperature, and these would be based on the total annual cost for owning and operating the system.

REFRIGERATION REQUIREMENTS

The proposed Dallas Food Distribution Center has 70 rooms which require 1,272 tons of refrigeration as shown in table 1.

Table 1.--Summary of refrigeration requirements by types of rooms and use

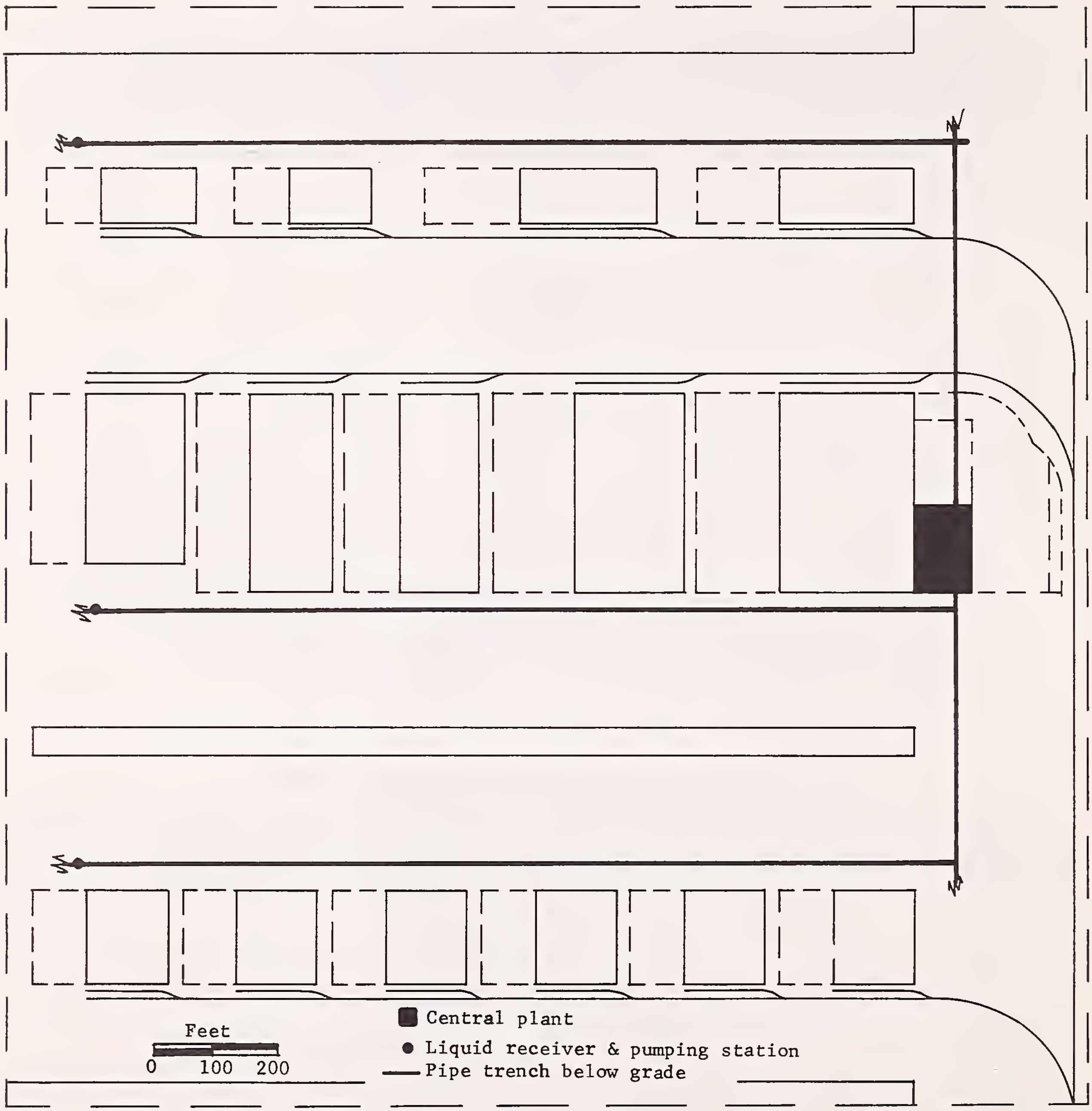
Types of rooms and temperatures	No. of rooms	No. of sq. ft	Ceiling heights (ft)	Tons of ref.	Sq. ft per ton
Freezer - 10° to 0° F	6	49,500	20	160.3	1/ 308.8
Coolers +32° to +45° F	20	101,610	20	392.5	258.9
Work Nominal +50° F	22	124,800	20	609.7	204.7
Office Nominal +72° F	22	32,215	8	109.8	293.4
Total	70	308,125	--	1,272.3	242.8

1/ 308.8 square feet per ton is relatively high because a large part of the space is in one large room.

Description of the Proposed Central System

Figure 1 illustrates the layout of a central refrigeration system for the proposed Dallas Food Distribution Center.

FIGURE 1
LAYOUT OF CENTRAL REFRIGERATION SYSTEM FOR THE PROPOSED FOOD DISTRIBUTION CENTER IN DALLAS, TEX.



Refrigeration produced in the central plant would be confined to three suction temperatures, 1/ the minimum number required to serve each of the three temperature ranges required by firms in the food distribution center. The table below summarizes the suction temperature details.

Table 2.--Summary of suction temperatures and uses

Suction temperature use	Temperature range (in rooms)	Nominal suction temperature	
		At terminal	At ref. plant
Frozen product storage---------	-10° to 0° F	-30° F	-35° F
Coolers-----------	+32° to +45° F	+20° F	+15° F
Workrooms and offices---------	+50° to +75° F	+35° F	+30° F

The central refrigeration plant would also circulate hot refrigerant gas throughout the system for defrosting evaporator coils and heating offices.

Each pipeline trunk would consist of a maximum of three refrigerant circuits, one for each of the three suction temperatures, plus a hot-gas circuit and an evacuation line. Each refrigerant and hot-gas circuit would consist of two lines, one for transporting the liquid refrigerant or gas to the terminal evaporators, and the other for returning the gas and residue liquid to the plant for recompression, extraction of heat, and recirculation. One evacuation line would be installed in each quadrant to evacuate refrigerants from the system in the event of a breakdown of equipment or malfunction in the distribution lines.

Each building in the food distribution center would be served by branch circuits that emanate from the trunk lines and extend to the various rooms requiring refrigeration. Each room would be served by one or more evaporator units, sized for the particular requirements of the area, and connected to the appropriate refrigerant circuit. Although refrigerants would be delivered to terminal evaporators in coolers and freezers at one of the three suction temperatures (-30°, +20° or +35° F), the desired temperature range for a refrigerated room would be obtained by selection of the proper size of evaporator coils, installation of a back-pressure valve at each evaporator unit, and by simple adjustment of a thermostat installed in each room. To air-condition offices, a +35° F refrigerant would be circulated through heat exchangers to chill tapwater that, in turn, would be circulated through heat coils in air-conditioning units. This same system can be used for heating

1/ "Suction temperature" is defined as the temperature at which a refrigerant will vaporize at a specific pressure.

as well as cooling by simply connecting the hot-gas circuits to the heat exchangers. Either hot or cold water would then be discharged from the heat exchangers and circulated through the air-conditioning units. The proper selection can be made by turning a control lever to the desired "summer" or "winter" position.

Required humidity levels could be obtained in all rooms by designing into the system the proper differential between the temperature of the refrigerant in the coils and the air temperature in the room. In instances where very high humidities are required (such as in wet coolers), a mechanical humidifier can be installed to disperse additional moisture in the air.

Facilities and Equipment

Central Plant Facilities

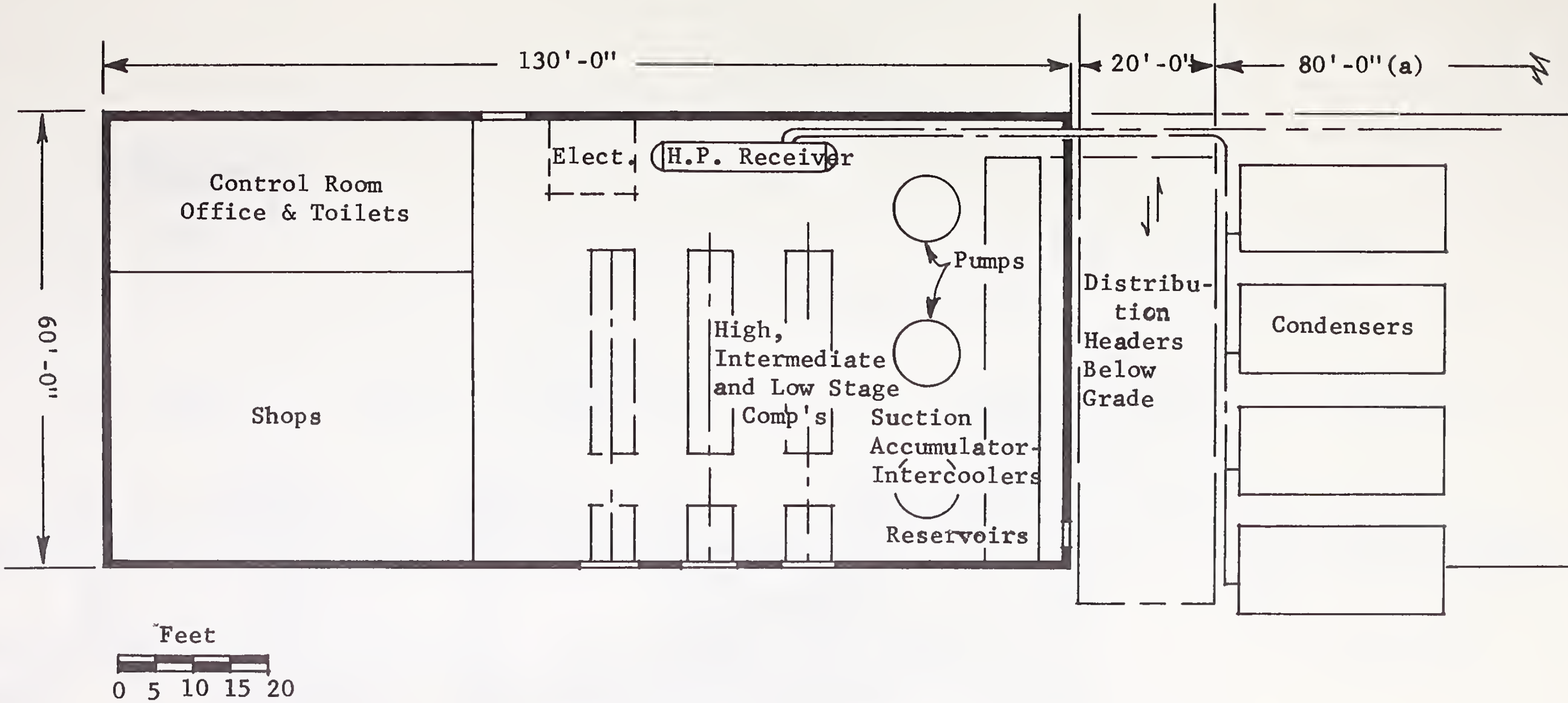
A building of approximately 9,800 square feet is required for the central refrigeration plant. In addition, an outside enclosure of 6,000 square feet is required for condensing equipment, water-cooling tanks, and header lines. Another 10,000 square feet of land is required for future expansion. A proposed location of the central plant is shown in figure 1, and a suggested layout of the proposed central plant facility is shown in figure 2. To accommodate high, vertical vessels and aid in ventilating the plant, the main part of the building should be constructed with a ceiling approximately 20 feet high. The areas of the plant to be used for support services (shops and offices) can be constructed with a lower ceiling of perhaps 12 feet. A cross section and a perspective of a typical refrigeration plant are shown in figures 3 and 4.

The proposed building can be erected at ground level with its walls constructed of masonry, concrete, or metal. Floor drains should be provided at appropriate locations. Floors should be sloped toward drain outlets 1/4 inch to the foot, constructed on high-density concrete, and painted to prevent spilled liquids from eroding the finish. Isolated concrete pads should be provided for the compressors and other major equipment. The building should be equipped with exhaust fans and air-intake vents to provide six air changes per hour. Lighting intensity should be provided at 75 foot-candles, tested 4 feet above the floor near critical equipment. Structural steel beams should be built into the roof over operating equipment to support at any one point as much as 3 tons of lift by an electric hoist.

Central Plant Equipment

To arrive at an estimate of the equipment required for a central refrigeration plant, it was necessary to decide first on the type of refrigerant best suited to the proposed system and then to select the equipment accordingly. After several alternatives had been evaluated, ammonia was chosen as the refrigerant. The primary reason for this choice is the greater refrigeration effect than other commonly used refrigerants. Smaller amounts are easier to circulate over the distances and in the quantities required for the complex.

FIGURE 2
SUGGESTED LAYOUT OF PROPOSED CENTRAL REFRIGERATION PLANT.



(a) Includes space for expansion of condenser area

FIGURE 3
CROSS SECTION OF PROPOSED CENTRAL REFRIGERATION PLANT.

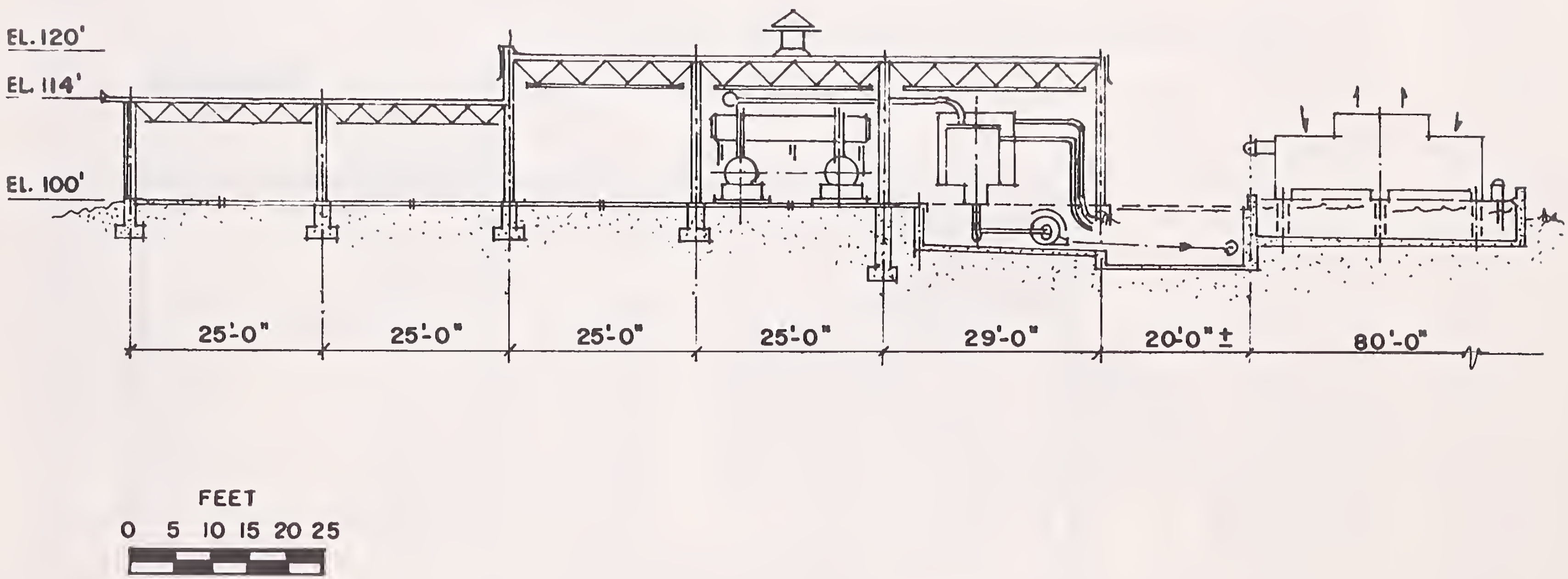
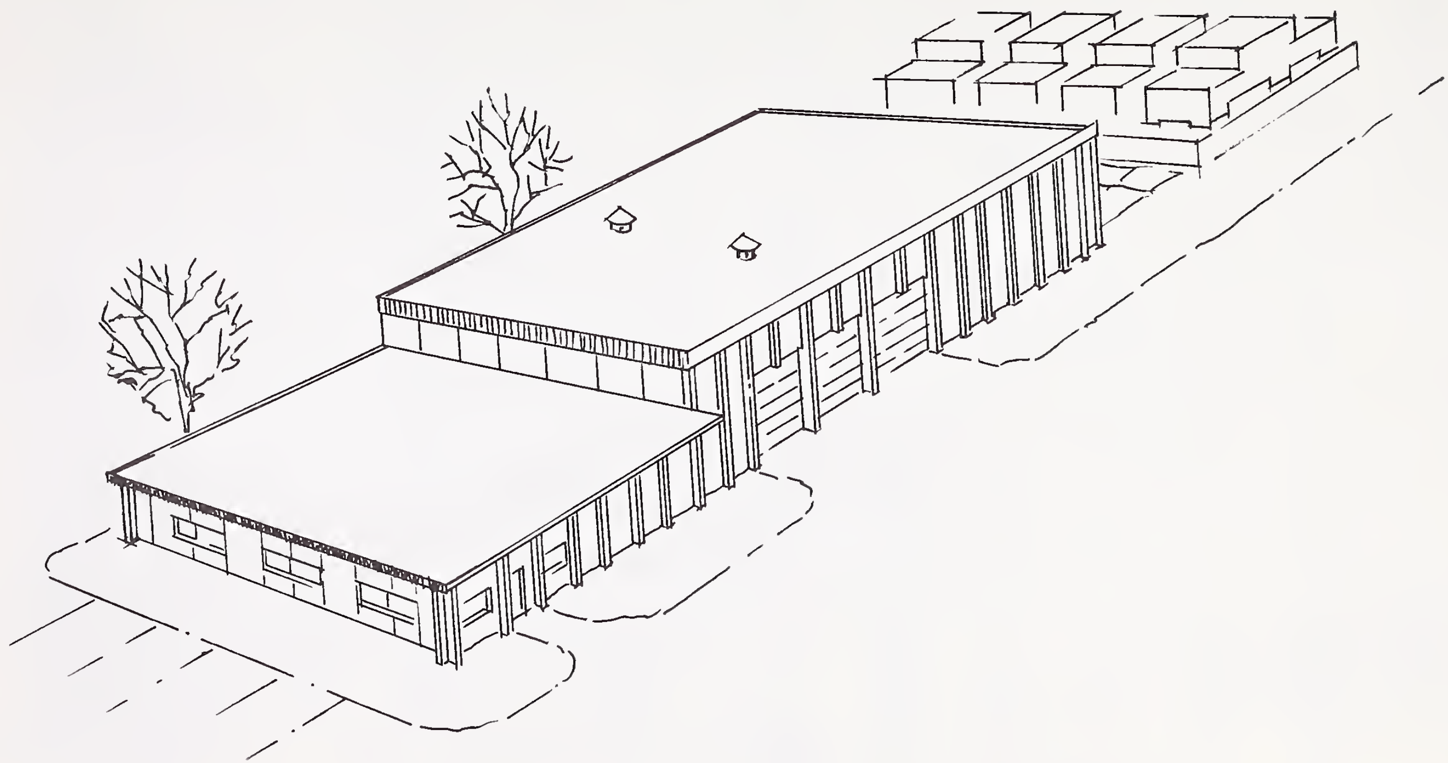


FIGURE 4
PERSPECTIVE OF PROPOSED CENTRAL REFRIGERATION PLANT.



Ammonia can also be handled to supply the diversified range of temperatures required by the firms proposing to locate in the distribution center. A circulated, rather than an expanded, ammonia system was selected, because it is the only workable arrangement in view of the considerable piping pressure losses encountered and the variation in evaporation pressure required.

The primary equipment required in the central plant for compressing and circulating ammonia is shown in figure 5. The ammonia refrigerant would be circulated throughout the system, as follows:

- Ammonia liquid would be pumped from the bottom of each accumulator tank through a header and into the quadrant circuits to be transported to terminal evaporators.

- Ammonia gas(and liquid) returning from terminal evaporators would be circulated back into each accumulator.

- Ammonia gas from the top of each accumulator would be drawn off by the compressors and compressed into a hot gas.

- The hot ammonia gas would be circulated through the condensers, where the heat would be removed and the gas liquified.

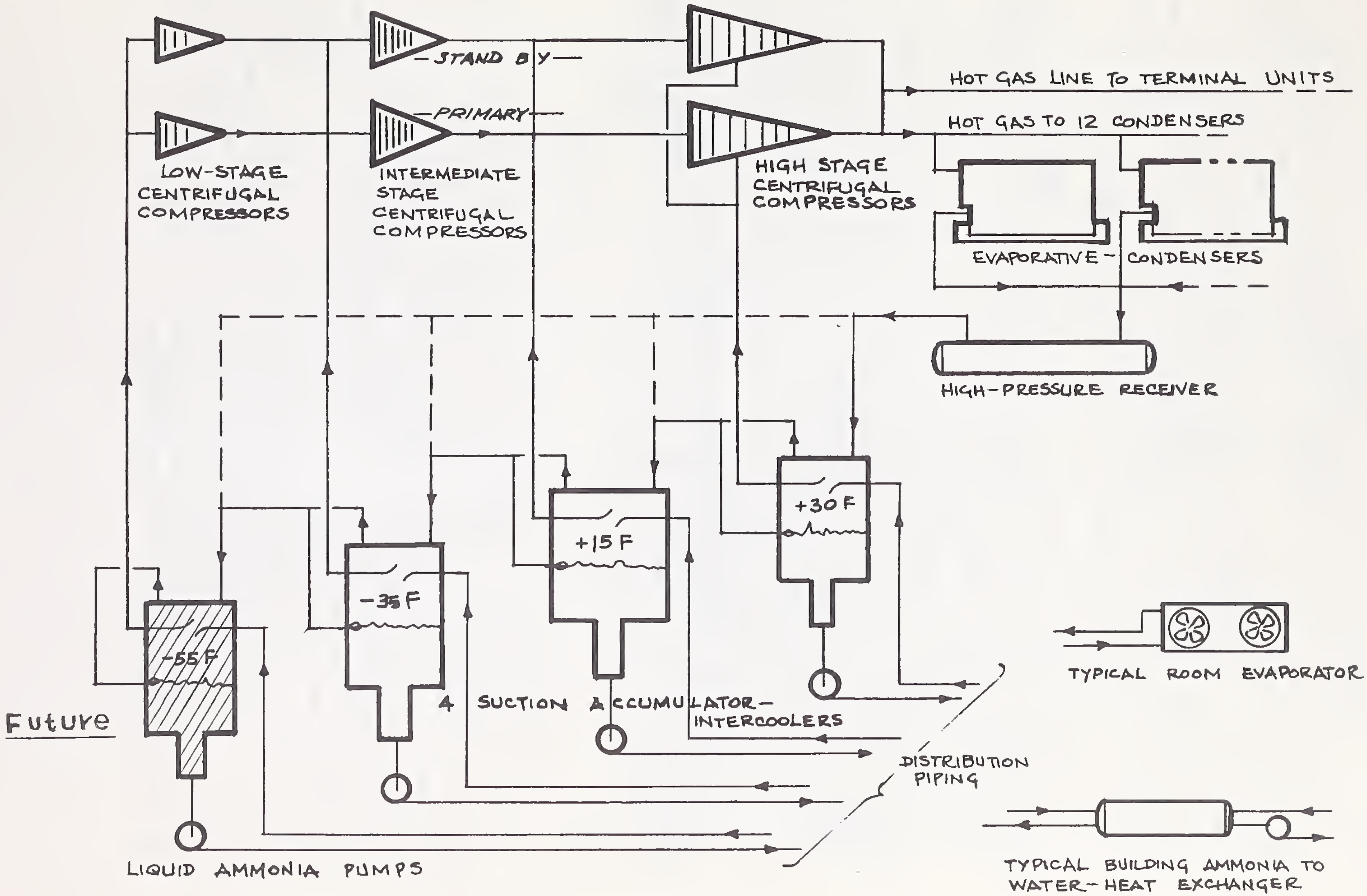
- Ammonia liquid from the condensers would be stored in liquid receivers, then transferred back to the accumulators where the cycle would be repeated.

At the heart of the circulated-ammonia system would be large, centrifugal, multistage compressors, installed to operate in series and in parallel. Each group of compressors would be connected in series to operate as a "system". Each compressor in one group would have an identical counterpart in the other group, and the identical units would be connected in parallel so that they could operate interchangeably. In this way, if one compressor requires maintenance, another compressor can carry the load. On an average day, one group of compressors could sustain the refrigeration load of the system. On peak days, both groups of compressors would need to operate at only 80-percent capacity to produce the maximum of 1,272 tons of refrigeration required by the system.

Other equipment in the plant, such as condensers, accumulators, receivers, pumps, etc., would be selected to be compatible with the compressors. According to the plan outlined in this report, the central refrigeration system would require three accumulator tanks (one of each suction temperature) and six condensers. The proposed system would also require two large vessels to be used as liquid receivers, one tank for gas pump-out, one large refrigerant reserve storage tank, approximately 10 pumps for circulating liquid refrigerants, a detailed control panel, and an assortment or other support equipment such as motors, valves, and interconnecting pipelines.

FIGURE 5

SIMPLIFIED ARRANGEMENT OF AN AMMONIA-COMPRESSING AND CIRCULATING SYSTEM FOR A PROPOSED FOOD DISTRIBUTION CENTER FOR DALLAS, TEX.



Circulation Lines

Approximately 57,300 lineal feet of pipelines in 5,300 lineal feet of trenches are required to circulate refrigerants to the 15 buildings in the food distribution center. A list of pipeline requirements and costs is shown in table 6. It is suggested that circulation lines be installed by burying them in the ground near the streets (see fig. 6). According to this plan, the refrigeration lines would be installed in a group and supported away from the sides and bottom of the trenches so that they could be easily insulated with foamed-in-place urethane. If installed in the manner illustrated in figure 6, all lines would be accessible for any necessary repair.

To facilitate the return of residual liquid to the central plant, it would be necessary to install at least one liquid receiver and accompanying pump in each distribution section, as shown in figure 1. Distribution lines would be sloped toward the receivers at an incline of 1 foot in 500 feet.

Final plans for installing the refrigerant distribution lines may depend on plans developed for installing other utility services in the area. As an alternative, the refrigeration lines could be installed in a walk-through tunnel, if such a facility were constructed for other utility services in the area. However, such an arrangement would significantly increase the cost of insulating the lines, since it would be necessary to install rigid insulation on the pipes manually rather than mechanically applied foamed-in-place urethane.

Control valves would be installed at points where branch lines run off the main circuits to service each building. Figure 7 illustrates a suggested method of extending branch lines into a typical building and distributing the refrigerants to the various terminal units.

Terminal Equipment

Each room requiring refrigeration or air conditioning would be equipped with an evaporator unit consisting of coils, fans, and controls. These units would be installed as shown in figures 8 and 9. A summary of evaporator equipment and estimated costs appears in table 7. Each evaporator unit would be connected to one of three refrigeration circuits, according to the suction temperature required. Evaporator units that require defrosting would be connected to a hot-gas circuit. Each evaporator would be connected to an evacuation line and equipped with drip pans and drain lines leading to stub-up drains at the floor for collecting and disposing condensate. Evaporators used to air-condition offices would operate in conjunction with heat exchangers as explained in the previous section. Each unit would be equipped for regulating fresh air intake and the flow of air over the coils. One heat exchanger would be installed in each building and connected to the 35° F suction circuit, the hot-gas circuit, and the city water supply.

FIGURE 6
SUGGESTED METHOD OF INSTALLING UNDERGROUND REFRIGERANT DISTRIBUTION LINES.

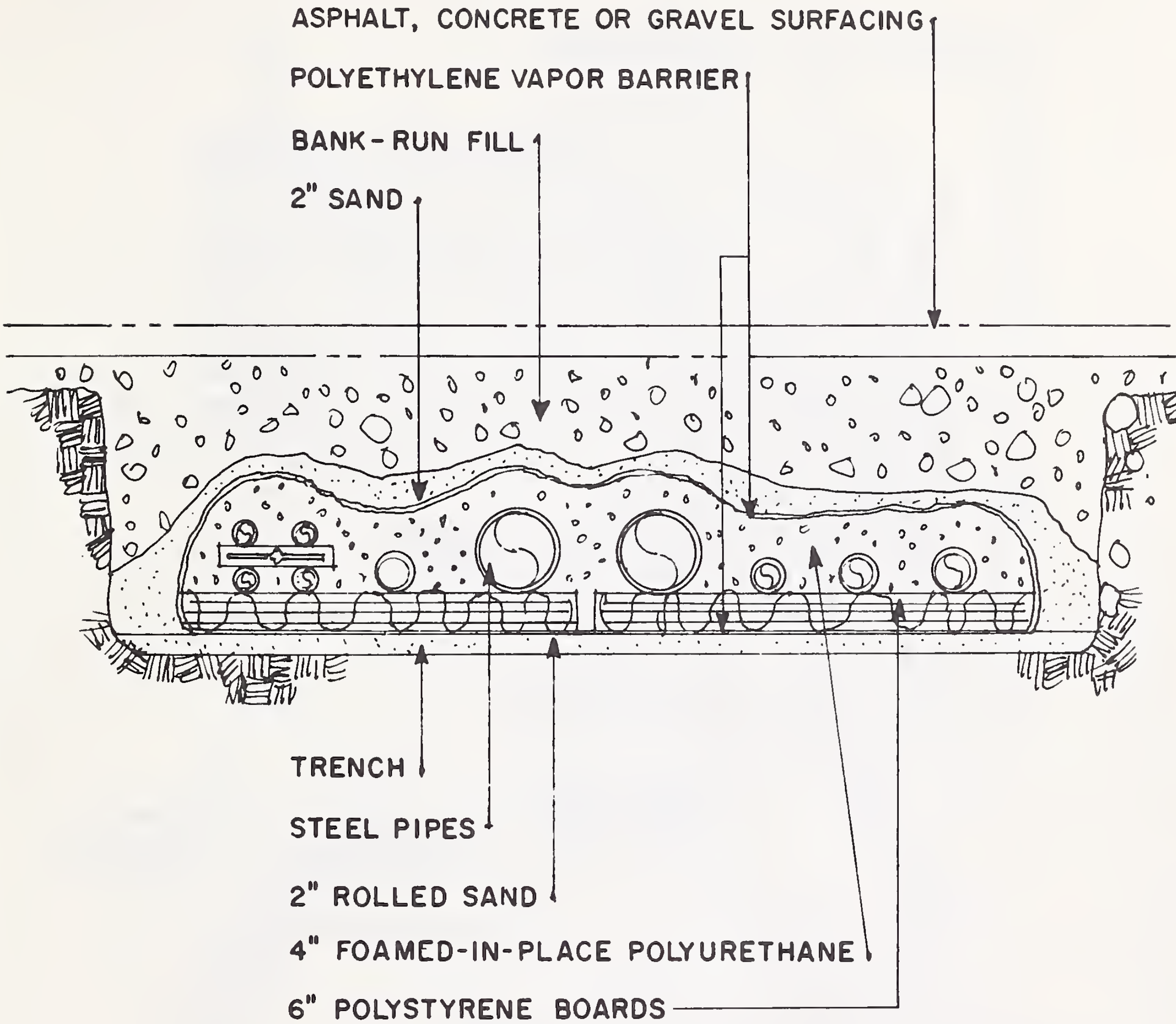


FIGURE 7
SUGGESTED METHOD OF EXTENDING BRANCH REFRIGERANT LINES INTO BUILDINGS.

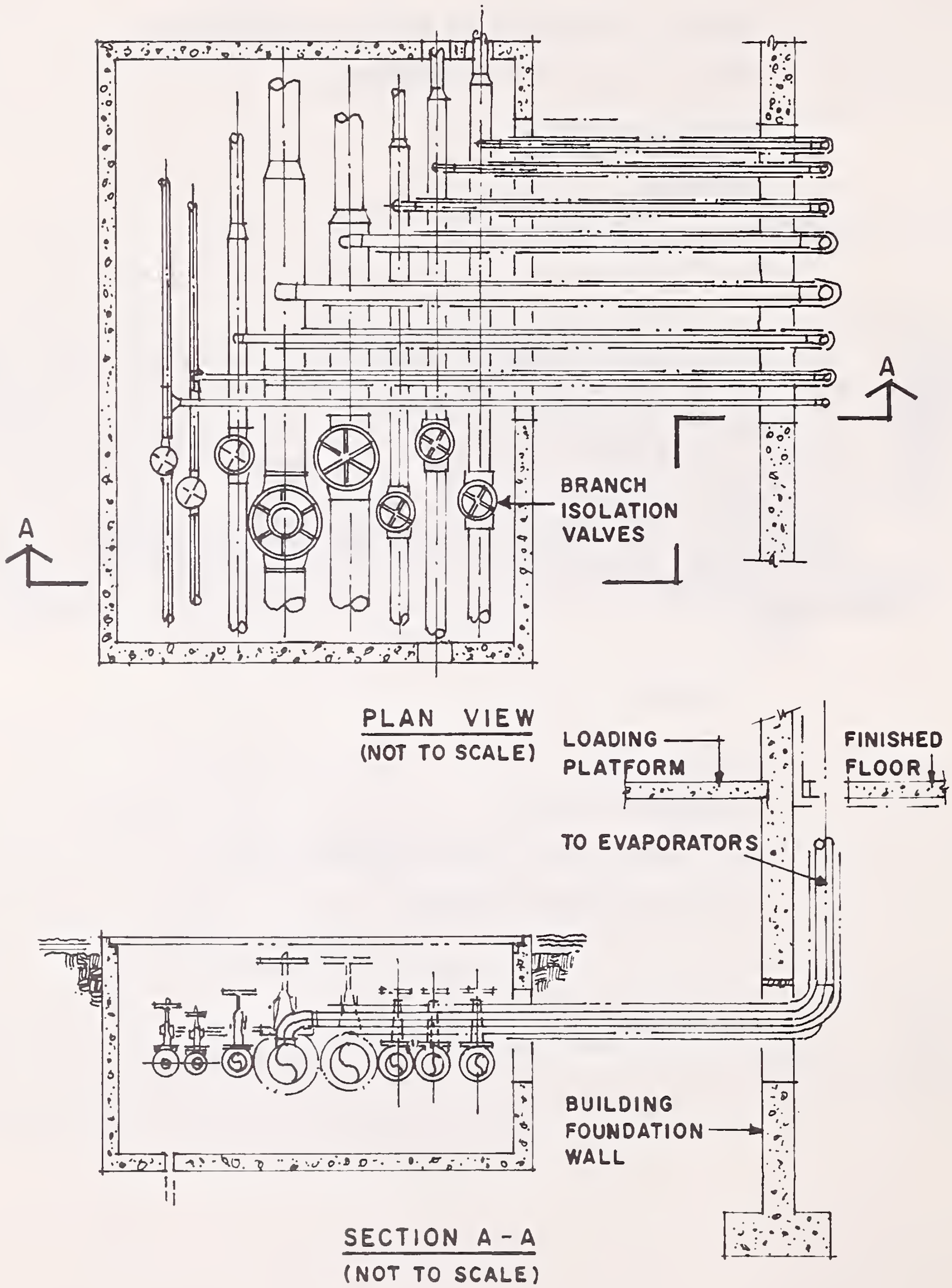
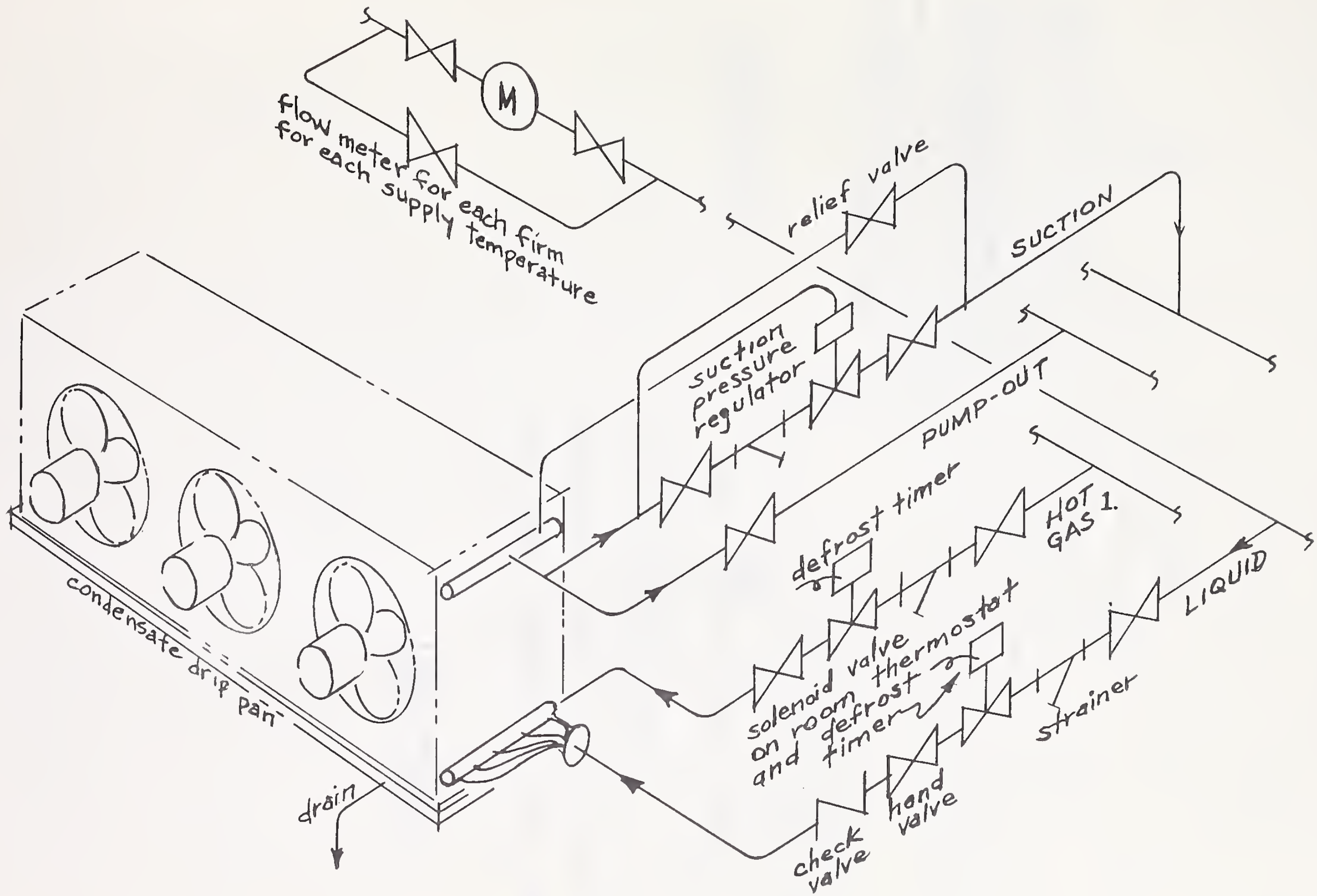


FIGURE 8

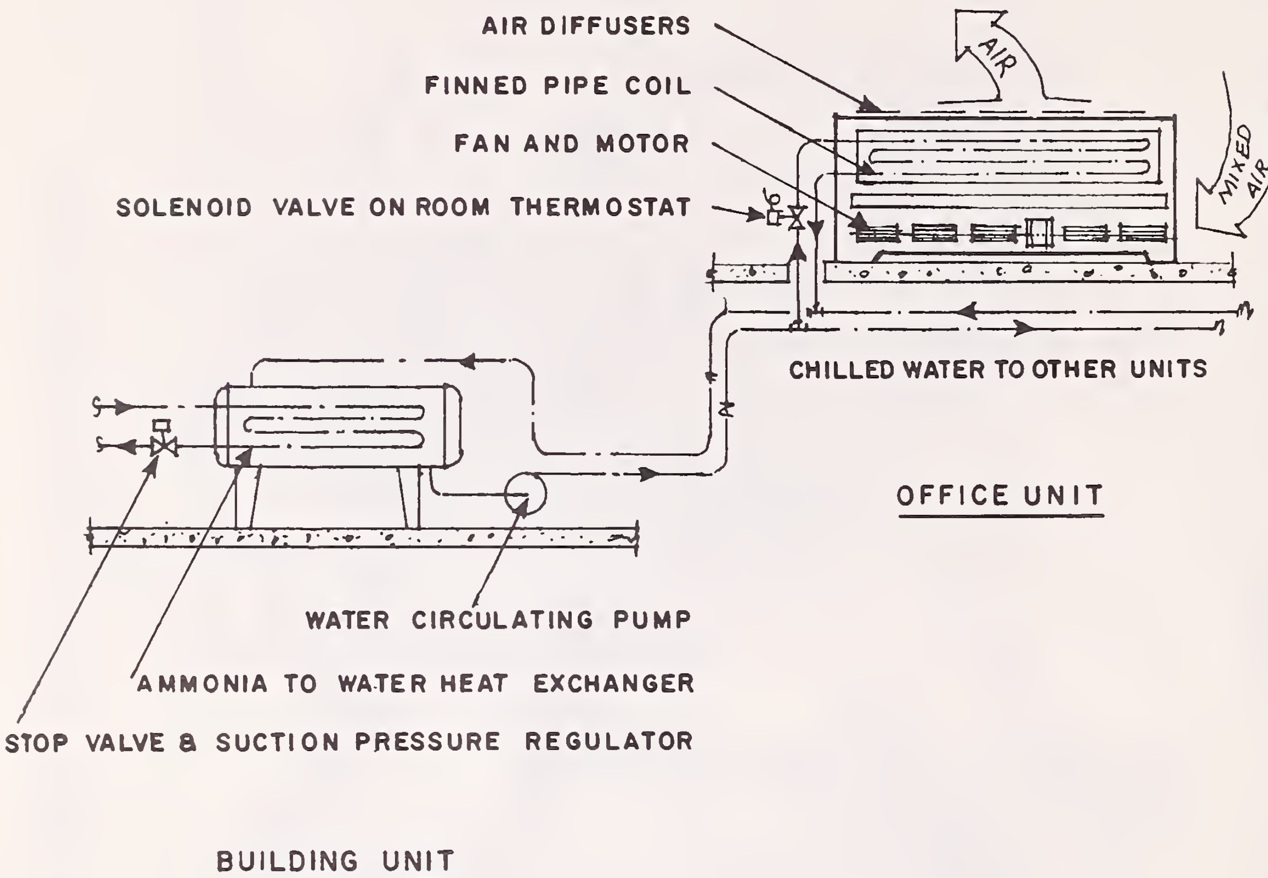
TYPICAL EVAPORATOR AND PIPING FOR ROOMS REQUIRING TEMPERATURES OF -10° to +65° F. 1/



[1] Hot gas defrost lines would be omitted on units in rooms requiring temperatures of above 36° F.

FIGURE 9

TYPICAL COIL AND FAN UNIT AND HEAT EXCHANGER
FOR AIR-CONDITIONING AND HEATING OFFICES.



Provisions for Expansion

Since it is anticipated that the peak of 1,272 tons of refrigeration for the food distribution center would occur less than 5 percent of the time, the system described in this report has a built-in excess capacity. This excess is estimated at 20 percent since the normal high demand is actually closer to 1,000 tons of refrigeration than it is to the 1,272 tons at peak requirements. For expansion beyond 20 percent, allowances are made in the central plant for a one-third increase in equipment without increasing the size of the building. Also, the central plant building can be extended to accommodate further expansion. To expand the refrigeration equipment capacity in the central plant, one or more complete groups of equipment can be added at a time. On this basis, the minimum addition would be three compressors accompanied by necessary equipment such as accumulators, receivers, etc.

The pipelines for the proposed refrigerant circuits are sized to accommodate a 20-percent increase in the capacity of each suction temperature. Additional expansion can be obtained by installing more circuits adjacent to the initial lines (see fig. 6).

COST OF FACILITIES AND EQUIPMENT

The total cost of a central refrigeration system is estimated to be a maximum of $2.1 million. A breakdown of this cost is summarized in table 3 below and further detailed in tables 4 through 7. The estimated cost of owning and operating the central refrigeration system, including the terminal units, is estimated at $703,100, as shown in table 8.

Table 3.--Summary of estimated costs of facilities and equipment for the proposed central refrigeration system

Facilities and equipment 1/	Reference	Estimated cost
Central plant facility------	Table 4	$172,500
Central plant equipment-----	Table 5	864,800
Distribution lines----------	Table 6	500,900
Terminal equipment----------	Table 7	575,000
Cost per ton----------------	2/	(1,661)
Total------------------		2,113,200

1/ Land is excluded, because this item is part of the total cost of the food distribution center.
2/ $2,113,200 divided by 1,272.3 tons = 1,661 (not included in total).

Table 4.--Estimated costs of central refrigeration plant

Items	Costs
Building shell 9,800 ft^2 @ $10/$ft^2$ -------------	$98,000
Outside work for condensers @ $5/$ft^2$ -----------	30,000
Other outside work-----------------------------	4,000
Steel support for hoists-----------------------	8,000
Lighting---------------------------------------	10,000
Fees and contingencies (15%)1/------------------	22,500
Total-------------------------------------	172,500

1/ A liberal allowance of 15 percent was used throughout to assist in establishing maximum estimated costs.

Table 5.--Summary of estimated costs of equipment for central refrigeration plant 1/

Description of equipment	Estimated cost to contractor
Two centrifugal compressors-----------	$178,000
Drive motors, high-speed gear units, related items----------------	64,000
Condensers and related items----------	77,000
Receivers, intercoolers, tanks, auxiliary compressors, and related items----------------------	63,000
Special valves, level controls, sensors, and fittings--------------	48,000
Fabricated piping and insulation------	58,000
Integrated automatic controls---------	73,000
Electrical transformers---------------	13,000
Installation 2/----------------------	178,000
Fees and contingencies (15%)----------	112,800
Total---------------------------	864,800

1/ Based on estimates from manufacturers and contractors.
2/ Includes $65,000 for refrigerant and includes markup on equipment and materials.

Table 6.--Estimated costs of refrigerant distribution lines 1/

Diameter of pipe	Lengths required	Pipe cost per 100 feet	Cost 2/
Inches	Lineal feet		
14	340	$665	$2,300
12	220	525	1,200
10	3,000	410	12,300
8	4,800	295	14,200
6	4,000	205	8,200
5	6,400	150	9,600
4	6,200	120	7,400
3½	3,900	105	4,100
3	6,500	90	5,900
2½	4,800	65	3,100
2	4,300	40	1,700
1½	7,100	30	2,100
1	10,800	25	2,700
½	2,000	25	500
Subtotal	64,360	--	75,300
Receivers, pumps, valves, and controls			48,800
Excavation, backfill, concrete pits, and labor			64,000
Installation of pipes and accessories			162,000
Insulation installed			92,000
Fees and contingencies (15%)			58,800
Total			500,900

1/ Based on estimates from manufacturers and contractors.
2/ Figures in Columns 2 and 4 rounded to nearest 100. Column 4 = Column 2 x Column 3.

Table 7.--Estimated costs of terminal refrigeration equipment 1/

Type of room	Room temperature range 2/	No. of rooms	No. of sq. ft	No. of sizes	No. of units	Cost to contractor 2/
Frozen product storage-------------	-10° to 0° F	6	49,500	3	19	$38,000
Coolers-- low temperature-----	+32° to 38° F	20	101,610	5	68	116,000
Workrooms-------------	+50° to 65° F	22	124,800	3	63	107,000
Office air conditioning--------	+65° to 75° F	22	32,215	2	48	23,000
Subtotal----------------------------------		70	308,125	13	198	284,000
Heat exchangers 3/--				7	18	23,000
Controls, insulation, etc. 4/----------------------------------				-	-	88,000
Installation 5/--				-	-	105,000
Fees and contingencies (15%)----------------------------------				-	-	75,000
Total---				--	--	575,000

1/ Based on estimates from manufacturers and contractors.
2/ Figures in Column 7 rounded to nearest $1,000
3/ For air conditioning.
4/ Valves, thermostats, hardware, pipe, and sundry supplies, including electrical accessories.
5/ Includes markup on equipment and materials.

Table 8.--Estimated annual cost of owning and operating the proposed central refrigeration system 1/

Item	Footnote reference number	Annual costs (rounded)	Total
Building occupancy			
Depreciation @ 25 years-----	1	$6,900	
Maintenance and repairs-----	2	3,500	
Cost of financing----------	3	15,500	$25,900
Central plant equipment			
Depreciation---------------	4	57,700	
Parts and supplies---------	5	8,700	
Refrigerant----------------	6	3,300	
Electrical power-----------	7	129,500	
Miscellaneous--------------	8	5,700	
Cost of financing----------	9	77,800	282,700
Distribution lines			
Depreciation---------------	10	33,400	
Parts and supplies---------	11	5,000	
Cost of financing----------	12	45,100	83,500
Terminal equipment			
Depreciation---------------	13	38,300	
Parts and supplies---------	14	5,800	
Cost of financing----------	15	51,800	95,900
Administration of system			
Payroll--------------------	Table 9	132,000	
Other expenses-------------	16	13,200	
Vehicle lease and operation-	17	6,000	151,200
Subtotal----------------		---	639,200
Earnings and reserve minus 10%			63,900
Total------------------	18		703,100
Deduct terminal equipment-----			95,900
Net total for calculating refrigeration charges-------	19	---	607,200

1/ See footnotes to table 8, page 23, for explanations for Column 3.

1. Cost of central plant building: $172,500 from table 4 divided by 25 years' depreciation = $6,900.

2. 1/2 of depreciation rate: $6,900 divided by 2 = $3,450.

3. 9-percent average annual interest and other financing charges: $172,500 x 0.09 = $15,500 average first 3 years.

4. Cost of central plant equipment $864,800 from table 5 divided by 15 years' depreciation = $57,700.

5. Parts and supplies = 1 percent of cost, i.e., $864,800 x 0.01 = $8,648.

6. Refrigerant replacement cost = 5 percent of $65,000 =$3,250 initial cost. See table 5, footnote 3.

7. $129,500. Based on a calculated 14 million kWh at 80 percent of capacity and calculated at Dallas industrial rate x 15 percent for contingencies = $0.00925.

8. 10 percent of depreciation: $57,000 x 0.10 = $5,700.

9. 9-percent average annual interest and other financing charges: $864,800 x 0.09 = $77,800 average first 3 years.

10. Cost of distribution lines: $500,900 from table 6 divided by 15 years' depreciation = $33,400.

11. Parts and supplies = 1 percent of cost, i.e., $500,900 x 0.01 = $5,000.

12. 9-percent average annual interest and other financing charges: $500,900 x 0.09 = $45,100 average first 3 years.

13. Cost of terminal equipment: $575,000 from table 7 divided by 15 years' depreciation = $38,300.

14. Parts and supplies = 1 percent of cost, i.e., $575,000 x 0.01 = $5,800.

15. 9-percent average annual interest and other financing charges: $575,000 x 0.09 = $51,800 average first 3 years.

16. 10 percent of payroll: $132,000 x 0.10 = $13,200

17. 30,000 miles @ 20 cents per mile for one truck = $6,000.

18. $703,100 divided by 1,272.3 tons of refrigeration = $553 per ton.

19. $607,200 divided by 1,272.3 tons of refrigeration = $477 per ton.

Table 9.--Estimated personnel required for maintenance, repairs, and administration of the proposed central refrigeration system

Assignment	Number of people	Annual cost
Manager and chief engineer------	1	$15,000
1st-class operating engineers---	1	11,000
2nd-class operating engineers---	1	10,000
Chief electrician--------------	1	10,000
Chief pipefitter---------------	1	10,000
Electricians-------------------	2	16,000
Pipefitters--------------------	2	16,000
Welders------------------------	1	8,000
Meter reader-------------------	1	8,000
Supply clerk-------------------	1	8,000
Administrative clerk-----------	1	8,000
Subtotal------------------	13	120,000
10-percent payroll burden-------		12,000
Total---------------------		132,000